Absolute Measurements of a Resistance by a Method based on that of Lorenz.

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(Communicated by R. T. Glazebrook, M.A., F.R.S. Received October 27,—Read December 11, 1913.)

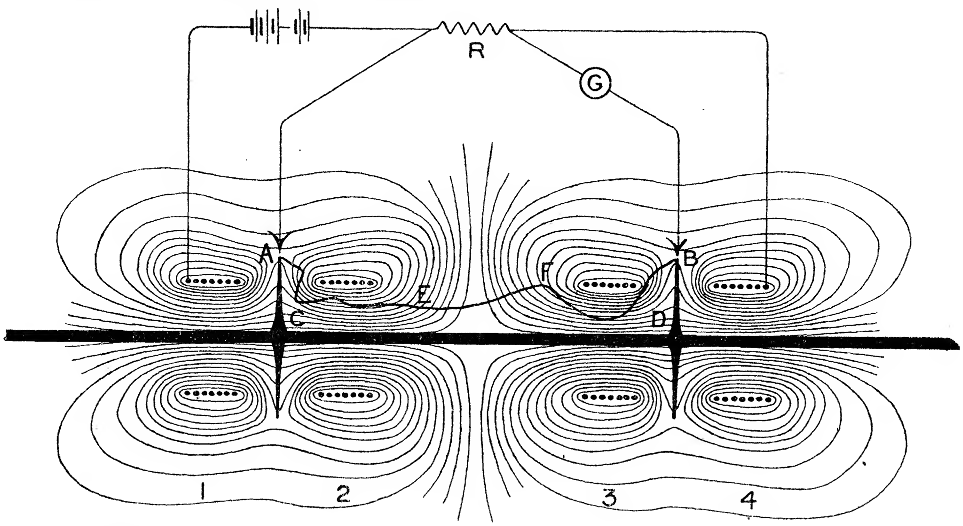
(From the National Physical Laboratory.)

(Abstract.)

The instrument described commemorates the work of the late Prof. Viriamu Jones. Its construction was rendered possible by a generous grant of money by the Drapers' Company of London, and by the kindness of Sir Andrew Noble, who provided the heavier metal portions of the instrument at very much less than the cost price.

The instrument differs from all other forms of apparatus based on the method of Lorenz, inasmuch as two discs are employed instead of one, thus practically eliminating the effect of the earth's magnetic field.

The magnetising coils are four in number. They are wound in single layers on marble cylinders, and the disposition of the coils with respect to the discs is such that the resulting magnetic fields through the discs are opposed in direction and the intensity of the field at points in the neighbourhood of the edge of a disc is of zero value, or nearly so. A diagrammatic sketch of the arrangement is shown in the figure.



Each of the two discs supports ten insulated phosphor-bronze segments placed at equal distances around its circumference, and the ten segments on one disc are connected to those on the other disc by ten conducting wires passing through the centre of the shaft. When the wires rotate with the discs a difference of potential is produced between their ends. The ten conductors are treated as five sets of two, and the five sets are at times placed in series by means of ten brushes (five to each disc), and at other times they are placed in parallel. The difference of potential produced by rotation is balanced against that on a standard resistance, R, through which the same current flows as through the coils. The resistance R can thus be found in terms of the mutual inductance of the coils and brush contact circles and the rate of rotation of the conductors. The difference of potential produced by the rotation of a conductor is dependent on the position of its ends only, and not upon its shape. Thus the difference of potential at the extremities of a conductor ACDB (see figure) is not altered if its shape is changed to AEFB.

The brushes consist of thin phosphor-bronze wires, stretched by two spiral springs, and resemble violin bows. Each brush makes contact with one or two segments over a length varying from 5 to 6 cm. and leaves a segment at a tangent, thus making the pressure greatest at the mid-point of contact. Petrol is employed as a lubricant for the brushes and is fed continuously to the surfaces of the segments.

The coils are wound with bare copper wire in double-threaded screw grooves cut on the surfaces of the cylinders. The two wires on any one cylinder form two adjacent helices, which may be connected in series or in parallel; an insulation test may be made between them. There are eight helices in all and these are connected by means of small concentric cables to a plug board and commutators, which enable the direction of the current in any coil to be changed at will.

Each cylinder is mounted on a strong metal support and its position with respect to a disc may be altered with ease by screw adjustments. The distance between the mid-planes of two coils is measured by means of microscopes.

An electric motor is used for driving. It is situated at a considerable distance from the coils and its influence as a mass of iron on the mutual inductance of the coils and brush contact circles has been experimentally shown to be not greater than one part in 10,000,000. A commutator is fixed to the axle of the motor, and this serves to charge and discharge a condenser placed in one arm of a Wheatstone bridge; by keeping the bridge permanently balanced the speed of the Lorenz apparatus is main-

tained constant. A directly driven chronograph enables the speed to be calculated.

Careful tests were made of the magnetic quality of all parts of the instrument, and, with the exception of the motor, I am satisfied that the magnetic permeability of no portion exceeds unity by more than two parts in 100,000.

The diameters and axial lengths of the coils were measured on three occasions and the results show that the dimensions have not changed by more than 3/1000 mm., equivalent to one part in 120,000. The diameters were measured with a current of 2 ampères circulating in the coils, and the increase in diameter produced by the heating was measured with considerable accuracy.

The diametral distance between opposite segments on a disc is about 54 cm., and when a disc rotates 1100 times per minute the diametral distance is found to increase by 0·09 mm.

The calculation of the mutual inductance of the coils and brush contact circles allows for the conicality of the coils and for the variation in pitch. Allowance is also made for the change in mean diameter of the coils during a measurement of resistance.

Electrical methods were adopted to set the coils coaxial with the shaft, and proved to be extremely sensitive. The error involved by any departure from the coaxial position may be made negligible even for measurements of high precision.

The resistances measured had nominal values of 0·001 ohm, 0·002 ohm, and 0·01 ohm. The observed values in absolute measure and the values in International ohms are given in the following table:—

No. of observations.		Resistance.			Difference, parts in 100,000. (Abs. × 10^{-9}) − (Int.).
		Standard.	Absolute measure, cm./sec.	In International ohms.	
28		0·001 ohm	100091_6	$0·00100039_3$	52_3
12		0·01 ”	100090_{10}	$0·0100038_3$	51_8
5		0·002 ”	Standard resistance varied		53_0
2	Coils 1 and 2 used	0·001 ”	100090_4	$0·00100039_3$	51_1
2	Coils 3 and 4 used	0·001 ”	100091_8	$0·00100039_3$	52_5

The International ohm is defined as the resistance offered to an unvarying electric current by a column of mercury, at the temperature of melting ice,

14·4521 grm. in mass, of a constant cross-sectional area, and of a length of 106·300 cm., while an ohm has a resistance of 10^9 cm./sec.

The agreement is most satisfactory.

The conclusion is that a resistance of 1 International ohm is equal to $1{\cdot}00052 \pm 0{\cdot}00004$ ohm (10^9 cm./sec.), the probable error of $\pm 0{\cdot}00004$ being approximately the sum of those involved in the resistance of the ohm and the International ohm. It follows that a column of mercury, at 0° C., $106{\cdot}245 \pm 0{\cdot}004$ cm. long, of constant cross-sectional area (the same as that of the International ohm), has a resistance of 1 ohm. The mass of this column will be $14{\cdot}4446 \pm 0{\cdot}0006$ grm.

I desire to express my thanks to the Drapers' Company of London and to Sir Andrew Noble for their generous help, to Lord Rayleigh for his keen interest in the work, and to Dr. Glazebrook for his very valuable help and advice throughout the investigation.

Elastic Hysteresis in Steel.

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(Communicated by Prof. B. Hopkinson, F.R.S. Received November 12,—Read December 11, 1913.)

The rate of dissipation of energy by internal molecular friction, when steel undergoes variations of stress within what is ordinarily regarded as the elastic limit, was the subject of a recent paper by Hopkinson and Trevor-Williams.* A bar of steel having an elastic range of about 25 tons per square inch was subjected to direct (axial) push and pull, the limits of tension and compression being equal, and the frequency of the cycles about 120 per second. The dissipation of energy by elastic hysteresis was determined by the fall of temperature between the middle point of the bar and the ends. It could be measured accurately in this way when the range of stress was near the elastic limit (25 tons per square inch) and could be detected when the range was 10 tons per square inch.

One object of the research just referred to was to ascertain whether the dissipation of energy per cycle of stress increased with the speed of reversal, in other words whether the internal friction to which this dissipation is

* 'Roy. Soc. Proc.,' A, vol. 87, p. 502.